GEOHYDROLOGY OF THE

DELTA-CLEARWATER AREA, ALASKA

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 80-92

PREPARED IN COOPERATION WITH THE
ALASKA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FOREST, LAND, AND WATER MANAGEMENT

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Dorothy E. Wilcox

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U.S. Geological Survey, Water Resources Division
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16. Abstract (Limit: 200 words)

The Delta Agricultural Project is developing more than 93 square miles of land in the study area. The alluvial aquifer there consists of lenticular, interbedded deposits of silt, sand, and gravel. Ground water is both confined and unconfined. The potentiometric surface slopes approximately north at [redacted] about 1 to 25 feet per mile. Well yields are as high as 1,500 gallons per minute from a well at Fort Greely. Water discharges from the aquifer into the Clearwater Creek network and Clearwater Lake, the mouth of the Delta River, and the Tanana River along the study area's northern boundary. From May 1977 to July 1979 flow at a gaging station on spring-fed Clearwater Creek ranged from 650 to 773 cubic feet per second. Average annual ground-water discharge is estimated at more than 1,200 cubic feet per second. The aquifer is recharged by seepage through [redacted] streambeds and by infiltration of precipitation. Hydrographs from observation wells reflect seasonal recharge pulses. Additional work is required to verify the following hypothesis: Losses from the Gerstle River, several small creeks draining the Alaska Range, and the Tanana River east of Clearwater Creek recharge the sections of the aquifer that discharge at the Clearwater Creek network. Losses from the Delta River and Jarvis Creek are the main sources of recharge to the sections of the aquifer that discharge near Clearwater Lake and Big Delta.

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GEOHYDROLOGY OF THE DELTA-CLEARWATER AREA, ALASKA

By Dorothy E. Wilcox

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-92

Prepared in cooperation with the ALASKA DEPARTMENT OF NATURAL RESOURCES

DIVISION OF FOREST, LAND, AND WATER MANAGEMENT

Anchorage, Alaska
1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U.S. Geological Survey
Water Resources Division
733 West 4th Avenue, Suite 400
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Multiply	By	To obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
feet per year (ft/yr)	0.3048	meters per year (m/yr)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
cubic feet per day per square foot of channel area	0.3048	cubic meters per day per square meter of channel area
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
degrees Fahrenheit (°F)	(°F-32)0.555	degrees Celsius (°C)

GEOHYDROLOGY OF THE DELTA-CLEARWATER AREA, ALASKA

By D. E. Wilcox

ABSTRACT

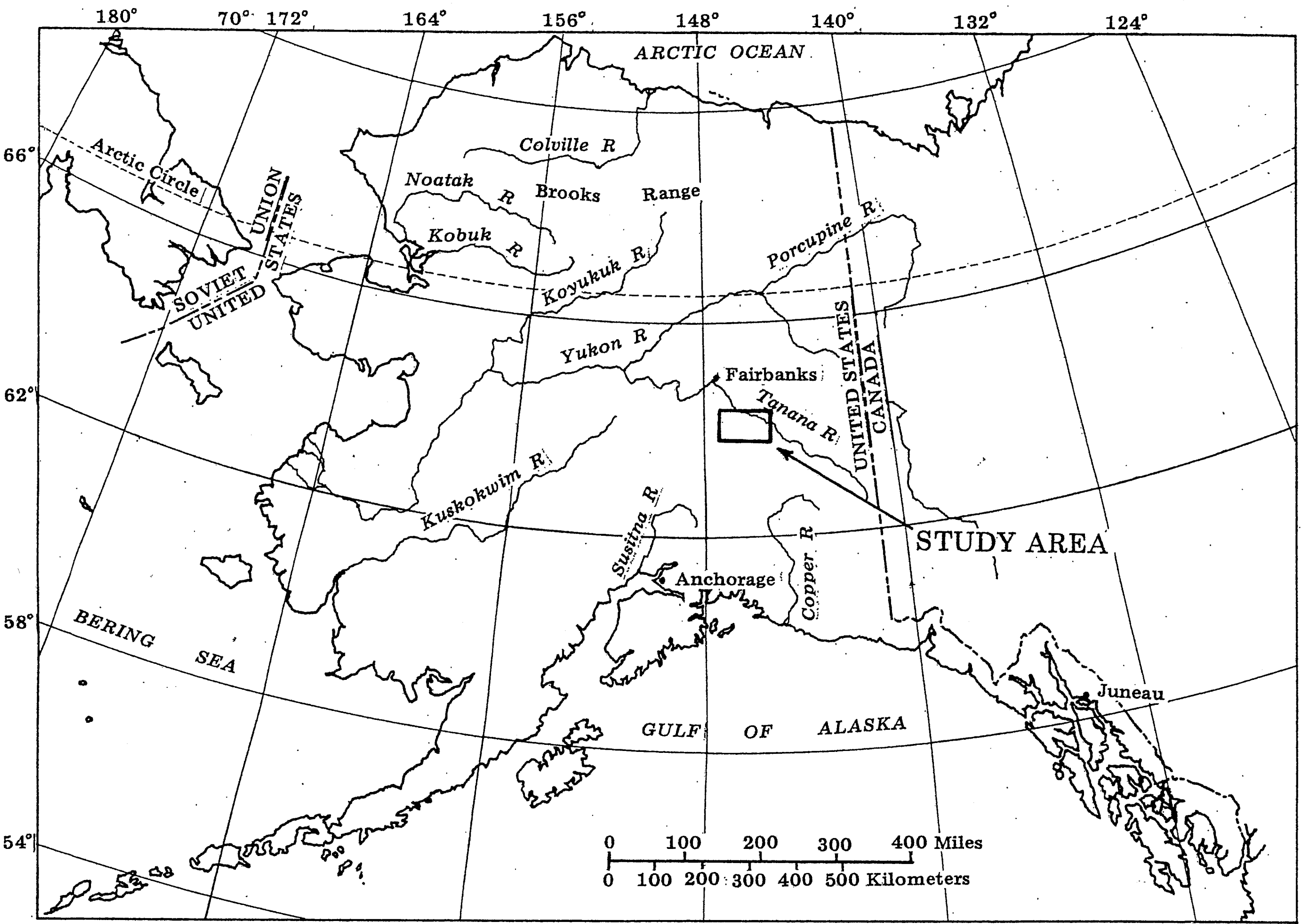
The Delta Agricultural Project is developing more than 93 square miles of land in the Delta-Clearwater area. Geohydrologic information can help planners, farmers, and environmentalists evaluate ground-water supplies and potential effects of development on ground and surface water.

The alluvial aquifer system underlying the Delta-Clearwater area is composed of lenticular, interbedded deposits of silt, sand, and gravel. Ground water here occurs under both confined and unconfined conditions. The potentiometric surface across the area slopes approximately northward at gradients ranging from about 1 to 25 feet per mile. Well yields are as high as 1,500 gallons per minute from a well at Fort Greely. Water discharges from the alluvial aquifer into the Clearwater Creek network and Clearwater Lake, into the mouth of the Delta River, and into the Tanana River along the northern boundary of the study area. The discharge rate from the aquifer shows little variation; from May 1977 to July 1979 flow at a gaging station on spring-fed Clearwater Creek ranged from 650 to 773 cubic feet per second. Average annual ground-water discharge is estimated to be greater than 1,200 cubic feet per second. The aquifer is recharged by seepage through the streambeds of rivers and creeks in the area and by infiltration of precipitation. Reaches of many rivers and creeks are perched above the aquifer and lose water to it. Hydrographs from observation wells in the area reflect seasonal recharge pulses.

The following ground-water flow system is hypothesized: Losses from the Gerstle River, losses from several small creeks draining the Alaska Range, and losses from the Tanana River east of Clearwater Creek recharge the sections of the aquifer that discharge at the Clearwater Creek network. Losses from the Delta River and Jarvis Creek are the main sources of recharge to the sections of the aquifer that discharge in the vicinities of Clearwater Lake and Big Delta. Additional work is needed to verify these hypotheses.

INTRODUCTION

The State of Alaska is conducting a development program, the Delta Agricultural Project (locally known as the Delta Barley Project), in the Delta-Clearwater area (fig. 1). Agricultural rights to more than 93 mi^2 of land were sold to farmers in 1978, clearing of the land was scheduled for completion by 1980, and the first crops were produced in 1979. The Barley Project area was largely undisturbed prior to this agricultural development program. Development will include stripping and burning of the native vegetation; introducing non-native crops; cultivating large areas of previously untilled land; applying agrichemicals to the land surface; and irrigating the land. The hydrology of the Delta-Clearwater area is an important consideration in this program because spring-fed creeks that are valuable recreation and salmon-spawning sites lie downslope from the agricultural development. The potential effects of agricultural activities on ground- and surface-water quality and flow are of interest to residents, planners and developers.



Adapted from U.S.Geological Survey Map C

Figure 1.--Location of the Delta-Clearwater study area.

The purposes of this study are to provide baseline hydrologic data and a geohydrologic interpretation for use in evaluating environmental changes in the Delta-Clearwater area that may be caused by agricultural development of the Delta Barley Project. Data are sparse in the interior of the study area, so the approach to the geohydrology was one of an investigation of boundary values, including aquifer properties, recharge, and discharge. Field observations summarized in this report were made from May 1977 through the summer of 1979.

The Delta-Clearwater area is bounded by the Gerstle, Delta, and Tanana Rivers and the north slope of the Alaska Range (fig. 2). It covers approximately 400 mi^2 and slopes gently northward from the base of the Alaska Range to the Tanana River. The peaks in the Alaska Range directly south of the area range from about 4,000 to 5,500 ft above the National Geodetic Vertical Datum of 1929 (NGVD). The lowest point in the study area is at the mouth of the Delta River, at approximately 1,000 ft above NGVD.

This report is a product of a cooperative water-resources investigation of the U.S. Geological Survey and the Alaska Department of Natural Resources. The author thanks Del Ivester and Earl Vegoren of Fort Greely, Lee Spears, Jim Harding, Mr. and Mrs. Norman Cosgrove, and Dean Cummings for access to water wells and other data-collection sites on their premises or under their authority.

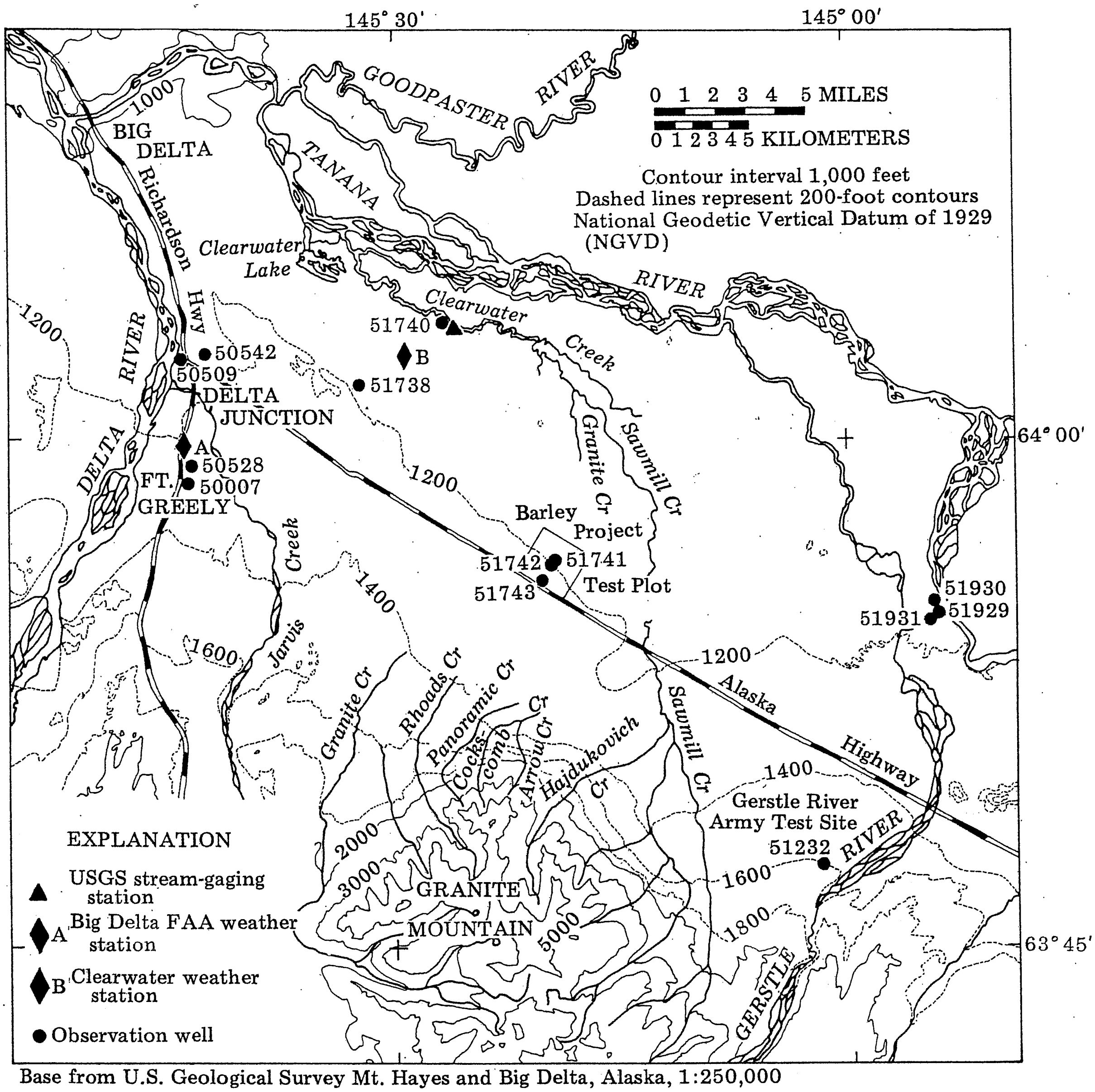


Figure 2.--Physical features and hydrologic stations in the Delta-Clearwater study area.

Previous Work

Péwé (1955) discussed the springs near Big Delta and the slope of the water table beneath the outwash plain. Holmes and Benninghoff (1957) prepared a terrain study of the Army test area at Fort Greely, which included permafrost, ground-water, and climatological data from the area and discharge data from Jarvis Creek. Data on ground water, surface water, water quality, and soils in the vicinity of Fort Greely were included in a report by the U.S. Army Corps of Engineers (1959). Waller, Feulner, and Tisdel (1961) mapped the potentiometric surface in the vicinity of Fort Greely. Reports by Waller and Tolen (1962a, 1962b) contain data on wells and springs along the Alaska and Richardson Highways. Péwé and Holmes (1964) published a geologic map of the Mount Hayes D-4 quadrangle which included some well data. The U.S. Geological Survey inventoried wells in the Big Delta, Delta Junction, and surrounding areas in 1965; these data are currently on file at the Geological Survey office in Fairbanks. Anderson (1970) authored a report o general hydrologic conditions in the Tanana basin. Williams (1970) discusse ground water, wells, and permafrost of the Delta area. Dingman and others (1971 made a hydrologic reconnaissance of the Delta River and its drainage basin. I 1972, the Tanana Valley Irrigation Study team reported on irrigation potential o the Tanana Valley. Pease (1974) collected some water-quality data and made a dis- charge measurement on Clearwater Creek.

Climate

The Big Delta Federal Aviation Administration (FAA) station has monitore local temperature and precipitation since 1942; the Clearwater station has bee recording data since 1964 (fig. 2). Three additional meteorological stations hav been recording data since the beginning of the Delta Barley Project in 1977. Graphs of monthly precipitation and average monthly temperature at the Big Delt station are shown in figures 3 and 4 for the years 1974-79 (National Oceanic an Atmospheric Administration, 1974-1979). The "normal" yearly average temperature and total precipitation at the Big Delta station are 27.4°F and 11.4 in., respectively. Precipitation was 0.33 in. greater than normal in 1977 and 3.12 in. less than normal in 1978.

GEOLOGY

Crystalline bedrock in most of the Delta-Clearwater area is overlain by thick sediments, including silt, sand, and gravel. Granodiorites and quartz monzonites are exposed on Granite Mountain in the southern part of the area. These rocks are in instrusive contact with pelitic schist south and west of the area (Holmes and Péwé, 1965).

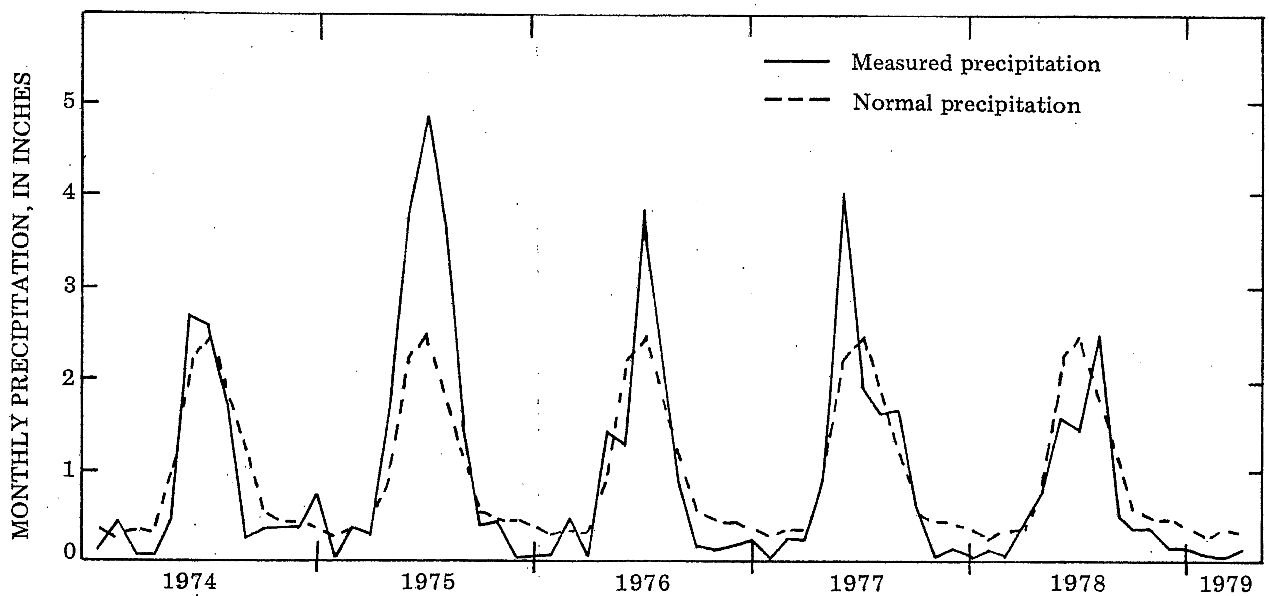


Figure 3.--Comparison of measured monthly precipitation with normal monthly precipitation at Big Delta. Climatological normals based on the period 1941-70 (National Oceanic and Atmospheric Administration, National Climatic Center, 1977).

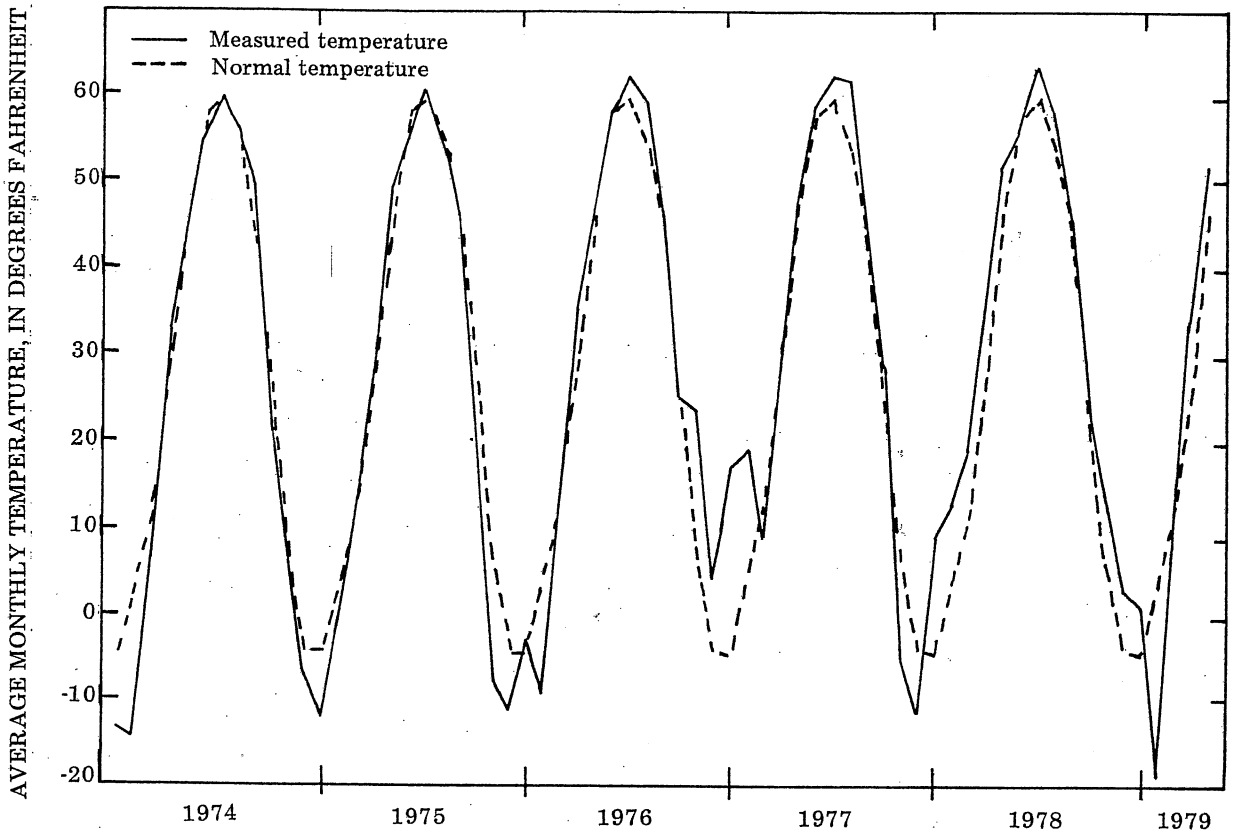


Figure 4.--Comparison of measured monthly average temperature with normal monthly average temperature at Big Delta. Climatological normals based on the period 1941-70 (National Oceanic and Atmospheric Administration, National Climatic Center, 1977).

Landforms in the study area include coalescing alluvial fans, moraines, and river flood plains. Broad alluvial fans of the Gerstle and Delta Rivers coalesce with the fans of small creeks entering the area from the Alaska Range to form a continuous alluvial apron at the base of the range. The Delta-Clearwater area was glaciated in at least three episodes (Péwé and Holmes, 1964). Terminal moraines are present in the Delta and Gerstle River valleys and in the valleys of several small creeks draining the north face of the Alaska Range. Wide flood plains have been formed by the Delta, Gerstle, and Tanana Rivers in the study area.

The Delta-Clearwater area is discontinuously underlain by permafrost. Drillers reported permafrost in five of 14 wells on Fort Greely. The depth of permafrost in the well holes ranged from immediately below seasonally frozen ground to as much as 217 ft below land surface. Permafrost has also been reported in wells near Delta Junction, at the Gerstle River Army Test Site, and along the Alaska Highway in test holes drilled at the Barley Project test plot (fig. 2). The water table is usually reported to lie below the permafrost layer (fig. 5). In many places, shallow permafrost causes poor drainage and wet soils. Farmers in the area report that melting of permafrost causes thermokarst features in some newly cleared fields.

Permafrost is virtually impervious. However, significant quantities of water may flow upward through thawed conduits in otherwise extensive areas of permafrost. Thawed conduits are commonly evident at the land surface as springs, spring-fed ponds, or lakes.

HYDROLOGY

Surface water

The Tanana, Delta, and Gerstle Rivers and Jarvis Creek are glacier fed and have broad, braided streambeds. Jarvis Creek at the Richardson Highway and the Gerstle River at the Alaska Highway are generally frozen solid during the winter; little or no flow is present from late fall until early spring. However, area residents report that aufeis (overflow ice) forms near the heads of these rivers during the winter. Aufeis formation indicates ground-water discharge. The Delta River also is frozen solid along much of its length during the winter, but discharges of approximately 30 ft³/s have been measured from springs flowing at its mouth. Discharges measured on the Delta and Gerstle Rivers and Jarvis Creek are listed in table 1.

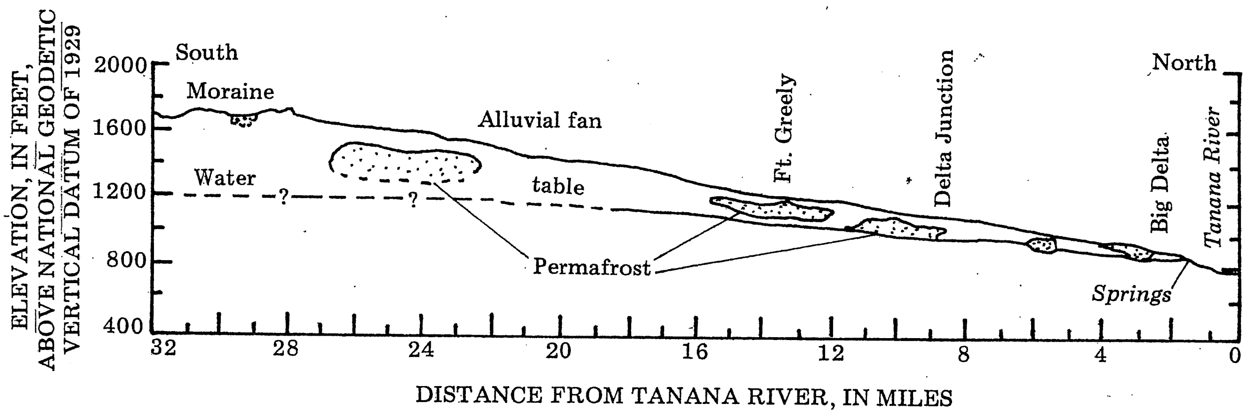


Figure 5.--Schematic drawing of permafrost and ground-water relations in the western Delta-Clearwater area (after Péwé, 1955).

The Tanana River receives relatively warm water from Clearwater Creek and the outlet of Clearwater Lake, which keeps the river open year-round at Big Delta. The Geological Survey maintained a gage on the Tanana River at Big Delta from 1948 to 1957. During the period of record the minimum discharge was 3,720 ft³/s on April 7, 1957; the maximum was 62,800 ft³/s on July 29, 1949. The average flow was 14,950 ft³/s.

Several small creeks entering the study area from the Alaska Range to the south have channels that extend only a short distance from the base of the mountains. Only Sawmill Creek has a channel that reaches as far north as the Alaska Highway. All these creeks appear to cease flowing during the winter, but aufeis in the upper reaches has been reported by local residents.

North of the Alaska Highway, near the toe of the continuous alluvial apron, lies a network of spring-fed creeks (Clearwater, Sawmill, and Granite Creeks), termed the Clearwater Creek network for purposes of this report, and spring-fed Clearwater Lake. Their flows, at specific sites, were measured in this study and are discussed later.

Sawmill and Granite Creeks each have upper and lower reaches that are not hydraulically connected, except possibly during periods of high flow. The upper reaches drain small valleys on Granite Mountain and commonly lose all their flow to the alluvial fan. Flow in the lower reaches heads at spring orifices north of the Alaska Highway.

Table 1.--Discharge measurements of rivers and creeks in the Delta-Clearwater area

	Date	Discharge (ft^3/s)
Gerstle River at Alaska Highway	08-25-1966	452
	09-15-1967	127
Jarvis Creek at Richardson Highway	07-23-1948	561
	09-18-1948	113
	07-07-1949	748
	05-21-1955	172
	05-24-1955	193
	06-07-1955	286
	06-16-1955	266
	06-20-1955	578
	06-23-1955	284
	08-03-1955	683
	08-26-1955	299
	09-30-1955	65
	11-04-1955	0
	01-31-1956	0
	03-02-1956	0
	05-09-1956	320
	06-13-1956	265
	07-21-1956	880
	08-25-1966	254
	09-16-1966	136
	06-15-1967	784
	06-27-1967	493
Delta River 1.8 miles south of Big Delta	08-24-1966	5,130
	10-19-1966	24
	05-17-1967	662
	06-14-1967	7,780
	07-18-1967	9,930
	09-14-1967	2,820
Sawmill Creek 3.0 miles upstream from Granite Creek	08-25-1977	49
Sawmill Creek 0.2 mile upstream from Granite Creek	08-25-1977	209
Granite Creek 0.1 mile upstream from mouth	08-25-1977	53
Clearwater Creek 0.1 mile upstream from Sawmill Creek	08-25-1977	135

Ground Water

Occurrence

The alluvial aquifer system in the Delta-Clearwater area is composed of thick sediments that overlie bedrock. From geophysical information, R. D. Reger (oral commun., 1979) estimated that bedrock is possibly as deep as 2,500 ft between the Delta River and Clearwater Lake, as well as south of Clearwater Lake. The thickness of saturated sediments may be nearly this great. The alluvium has been penetrated by wells to depths of 400 ft at Fort Greely and 549 ft at the Gerstle River Army Test Site.

The alluvial aquifer system may comprise several aquifers separated by leaky confining layers. However, paucity of data precludes dividing it into finer units. In this report, the entire alluvial aquifer system will be treated as a single aquifer with local confinement and will be termed the "alluvial aquifer" or "aquifer". Stratification due to lenticular deposits of silt, sand, and gravel with boulders causes permeability within the alluvial sequence to range widely.

Ground water occurs under confined conditions at Fort Greely (well 50007) and in the Barley Project test plot (wells 51741, 51742, and 51743). Drillers' logs of these and other wells in the area indicate that permafrost does not generally extend into the saturated zone and usually does not act as a confining layer (fig. 5). Silty sediments may locally confine the aquifer; Williams (1970) stated that at Fort Greely it is confined by till of the Delta Glaciation.

The aquifer is unconfined in the vicinity of wells at the Spears Farm (well 51738), near Clearwater Creek (well 51740), and near the Tanana River 18 mi upstream from the Gerstle River (wells 51929, 51930, and 51931).

Recharge to the Ground-Water System

The aquifer is recharged by losing streams along the western, eastern, and southern boundaries of the study area and by infiltration of precipitation.

Jarvis Creek and the Delta River are perched above the aquifer and lose water to it. Nearby wells at Fort Greely and Delta Junction have static water levels as much as 200 ft below the streambeds of these rivers. Waller, Feulner, and Tisdel (1961, p. 123) noted that the gradient of the water table in the vicinity of Fort Greely "indicates that the aquifer receives recharge from the Delta River to the west and probably discharges at the land surface to the northeast, in the Clearwater Lake area." Holmes and Benninghoff (1957) reported that Jarvis Creek loses large quantities of water into its streambed. A series of five discharge measurements made at each of four sites along Jarvis Creek in 1955 show that the seepage losses varied during the summer and with discharge. These seepage measurements indicated water losses as great as 3.5 $(ft^3/day)/ft^2$ of channel. Recharge to the aquifer by these rivers appears to be reflected by seasonal water-level fluctuations discussed in the "Water Levels" section.

Analysis of the study area indicates an unknown, probably substantial, amount of recharge through the streambed of the Tanana River along the eastern boundary of the study area. Three wells near the Tanana River 18 mi upstream from the Gerstle River were drilled to determine whether the reach of the river in this area loses water to the aquifer. Ground-water levels in the wells are approximately 30 ft below river level; thus the river in their vicinity is perched. Additionally, from water-level data collected from these three wells on October 15 and November 16, 1978, and July 19 and September 27, 1979, hydraulic gradients were computed. In October and November 1978 and September 1979, the gradient sloped west-northwest at 3-5 ft/mi; in July 1979 it sloped southwest at about 4 ft/mi. The water-table gradient and the relation of the river level to the ground-water level are evidence that losses from the Tanana River are recharging the aquifer in the reach near the wells.

During an August 1977 aerial reconnaissance, visual estimates of discharge of the Gerstle River indicated a losing reach from the point where the river exits a canyon on Granite Mountain and enters onto the alluvial fan to about 3 mi north of the Alaska Highway bridge. The ground-water level in well 51232 (fig. 2) at the Gerstle River Army Test Site, 3.5 mi south of the Alaska Highway and 1 mi west of the braided section of the river, is about 400 ft below the elevation of the water surface in the river. Seasonal water-level fluctuations of about 13 ft in the well may reflect recharge pulses to the aquifer from this section of the river. No ground-water data have been collected along the lower reaches of the Gerstle River.

Several small creeks draining the north face of the Alaska Range commonly lose all their flow into the ground near the apex of the continuous alluvial apron. In August 1977, during the aerial reconnaissance, the flow in Rhoads, Hajdukovich, Arrow, Cockscomb, and Panoramic Creeks, and the upper reaches of Sawmill and Granite Creeks was estimated at less than 10 ft^3/s each. During the overflight, no flow was observed in these creeks at the Alaska Highway. However, during the spring snowmelt period and during rainstorms in the Granite Mountain area, the discharge in the creeks increases greatly, and the flowing reaches of the streams lengthen in the downstream direction. The volume of ground-water recharge from each of these creeks is directly related to flow because all flow seeps into the ground except possibly during unusual storm events. During summers of 1978 and 1979, local residents reported flow in Sawmill Creek at the Alaska Highway bridge after a few heavy rains. On June 20, 1979, a flow of 5.2 ft^3/s was measured at the bridge; two days later the streambed was reported dry. The dry streambed of the upper reach of Sawmill Creek extends nearly as far north as the spring orifice at the head of the lower reach. During periods of extremely high runoff, surface flow in the upper and lower reaches of Sawmill Creek could conceivably connect; this could alter both the flow and the quality of water in the spring-fed creek network.

Discharge from the Ground-Water System

Water is discharged from the aquifer by springs in the northern and western parts of the study area. The major discharge areas are along the Clearwater Creek network, at Clearwater Lake, and at springs near the mouth of the Delta River. Ground water also discharges to the surface from the hydrologic system as spring-flow into the swampy areas near the Tanana River along the northern boundary of the study area and discharges out of the study area as subsurface flow beneath the beds of the Tanana and Delta Rivers near Big Delta.

The Clearwater Creek network is almost entirely spring fed. The major spring orifice in the network is at the head of Sawmill Creek. A flow of 50 ft^3/s was measured 0.2 mi downstream from this orifice in August 1977. Seepage measurements along Sawmill Creek in August 1977 showed a gain of 158 ft^3/s along 2.8 mi of channel. Discharges measured along the spring-fed creeks are shown in table 1. Discharge from May 1977 to July 1979 at the gaging station on Clearwater Creek near Delta Junction is illustrated by the hydrograph in figure 6.* Streamflow shows little variation; discharge ranged from 650 to 773 ft^3/s during the period of record. An aerial reconnaissance in December 1977 showed Clearwater Creek and the lower reach of Sawmill Creek were unfrozen, except for shore ice, along their lengths. The inflow of relatively warm ground water keeps these creeks open during the winter months, although the shore ice may be as thick as 2 ft.

Clearwater Lake also is almost entirely spring fed. A discharge of 463 ft^3/s was measured at the outlet of Clearwater Lake in September 1977. This is probably some measure of the ground-water discharge into the lake, but flow at the lake outlet is affected by changes in the volume of water stored in the lake, which is related to lake level. The rate at which ground water discharges to the lake also probably varies with the changing level of the lake surface. High-water marks on vegetation and rocks along the shores indicate that the lake level can fluctuate several tenths of a foot; the fluctuations may be related to the stage in the Tanana River. During the winter, ice covers the lake surface except where springflow maintains open water.

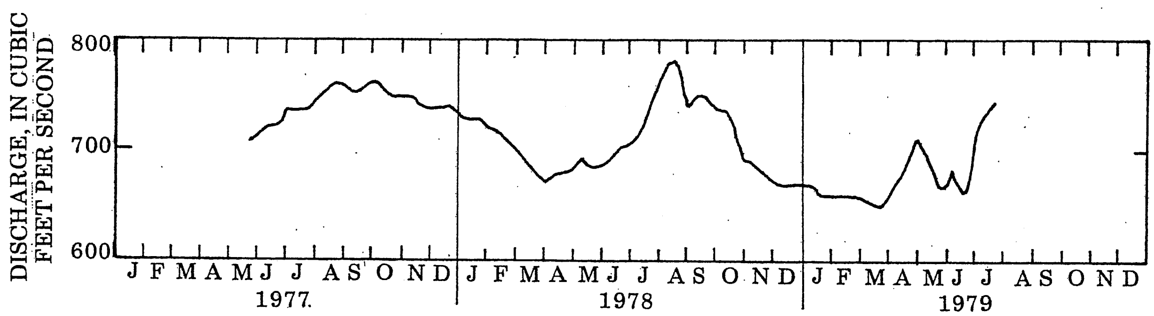


Figure 6.--Discharge hydrograph of Clearwater Creek at gaging station 15477500.

Several perennial springs occur at the mouth of the Delta River. Total discharge of these springs has been measured at about 30 ft^3/s in March of 1975, 1976, and 1977.

The year-round ground-water discharge rate from the hydrologic system in the study area is estimated to exceed 1,200 ft^3/s. This figure may be conservative because the discharge of Clearwater Creek at its mouth should be larger than at the gage, due to presumed spring inflow along the 7-mi reach downstream of the gage. Additionally, the reach of the Tanana River along the northern boundary of the study area receives significant but unmeasured seepage.

Aquifer Characteristics

Field-determined values of the transmissivity and storage are not available for the aquifer in the Delta-Clearwater area. A pumping test was attempted on the

*Three surface-water sites in the Delta-Clearwater area have U.S. Geological Survey downstream-order station numbers. They are listed in table A at the back of the text along with their corresponding latitudes and longitudes.

production well (51741) in the Barley Project test plot, but the resulting data could not be analyzed without ambiguity.

The presence of silty sediments in many areas may cause some sections of the aquifer to have relatively low transmissivity. However, the hypothesized large thickness of the alluvium and the presence of lenses of sand and gravel probably result in an overall high transmissivity for the alluvial aquifer. Well yields in the area are as high as 1,500 gal/min from a well formerly used to produce cooling water for the now-abandoned nuclear powerplant reactor at Fort Greely.

Water Levels

Ground-water data are available from some sections of the study area. Around the population centers of Big Delta, Delta Junction, and Fort Greely, wells and data are abundant; elsewhere, data are sparse. The potentiometric surface is more than 400 ft below land surface near the front of the Alaska Range, 150-200 ft near Fort Greely, 50-100 ft near Delta Junction, and less than 10 ft near Clearwater Creek, Clearwater Lake, and Big Delta. Waller, Feulner, and Tisdel (1961) reported that the potentiometric surface near Fort Greely sloped in a northeasterly direction at about 11 ft/mi from September through November 1959. Additional data compiled for this study show that the potentiometric surface across most of the study area slopes northward at gradients ranging from about 1 to 25 ft/mi; however, in some areas it slopes northeast and in others northwest.

Ground-water levels fluctuate in response to seasonal recharge pulses to the aquifer from river and stream channel losses and from precipitation. Residents in Delta Junction have reported fluctuations as great as 50 ft/yr in domestic wells. Hydrographs of four observation wells (figs. 7-10) show the seasonal trends clearly. All the hydrographs have a similar, roughly sinusoidal trace. The hydrograph for the Fort Greely well (fig. 7), which includes 4 years of continuous recorder data, shows that water levels are lowest in late May or early June. River ice breaks up in April or May, and the recharge pulse begins; the ground-water level rises until it reaches a peak in October. At this time the rivers freeze and recharge ceases. The ground-water level then recedes until May or June, when recharge begins again. However, silt may clog the streambed gravel and reduce permeability during much of the summer. Recharge may take place largely during periods of high flow when scouring and shifting of channels occur. Low and high water levels in the Spears Farm irrigation well (fig. 8) and the Geological Survey's Tanana test well (fig. 9) also occur in June and October, respectively. The lowest water level in the Barley Project well (fig. 10) was in July; the highest was in December.

The water levels recorded in the Fort Greely well during 1978 and 1979 are the highest for the 16 years of record. They may reflect delayed ground-water recharge from 1975, 1976, and 1977 (fig. 3) when summer rainfall was greater than normal at the Big Delta FAA station (National Oceanic and Atmospheric Administration, 1974-1979). Other ground-water levels measured during this study may also be above normal.

Hydrologic Flow

The hypothesized ground-water flow system is shown in figure 11. Data are insufficient to justify more than a gross conceptual model. The aquifer discharges at the Clearwater Creek network, at Clearwater Lake, and also at the mouth of the

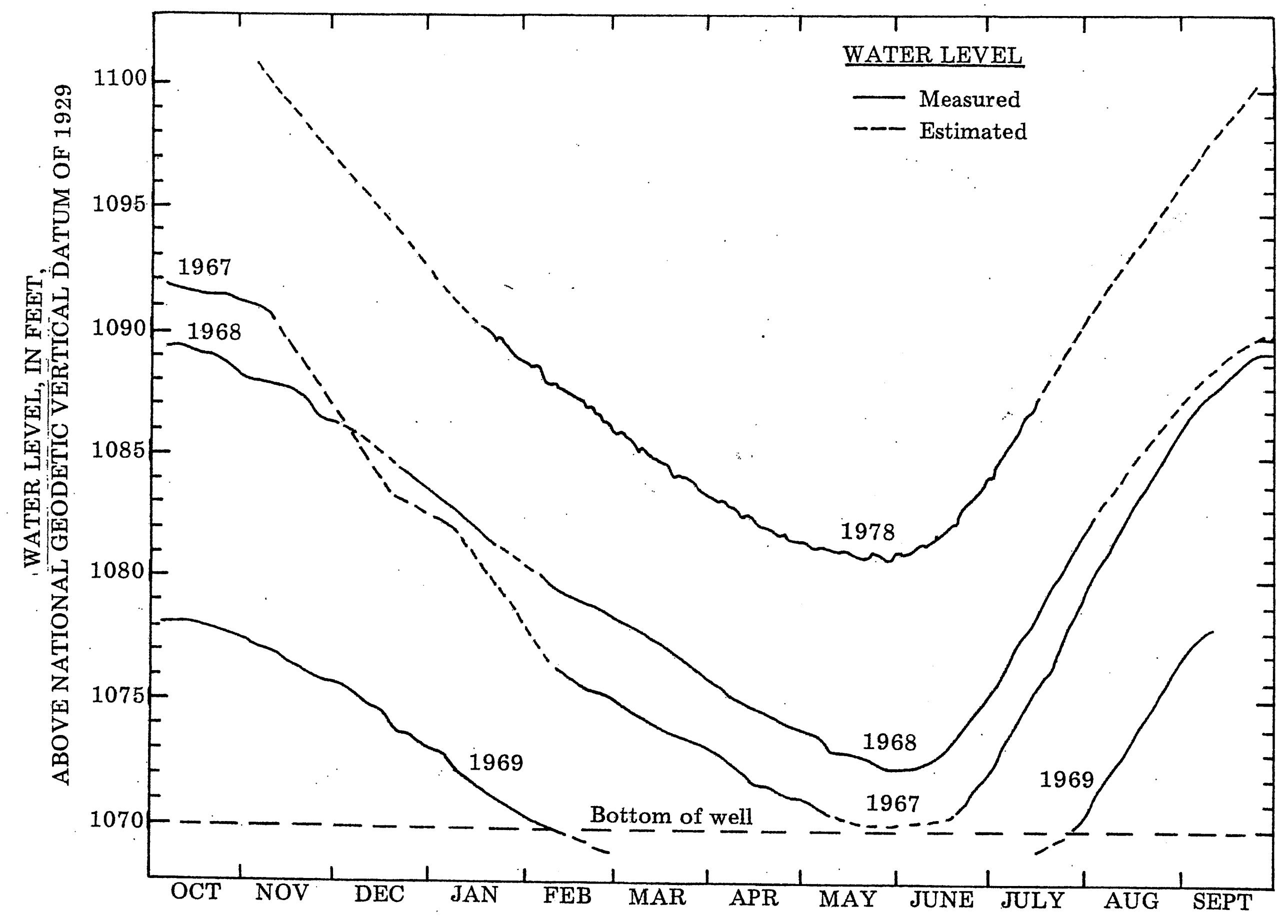


Figure 7.--Hydrograph of well 50007, Fort Greely No. 7.

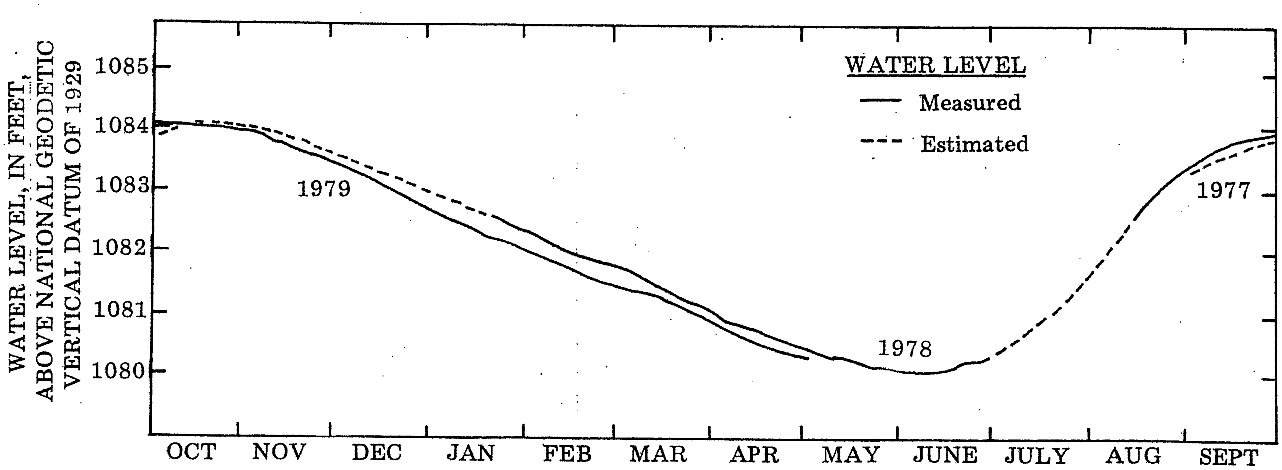


Figure 8.--Hydrograph of well 51738, Spears Farm.

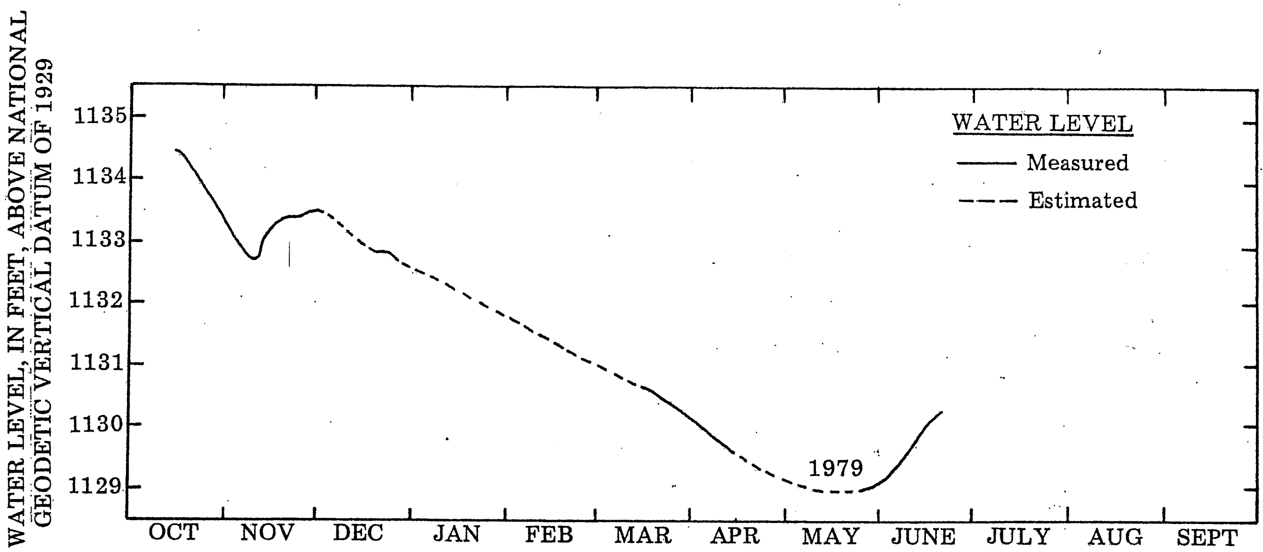


Figure 9.--Hydrograph of well 51930, U.S. Geological Survey Tanana Test Well No. 1.

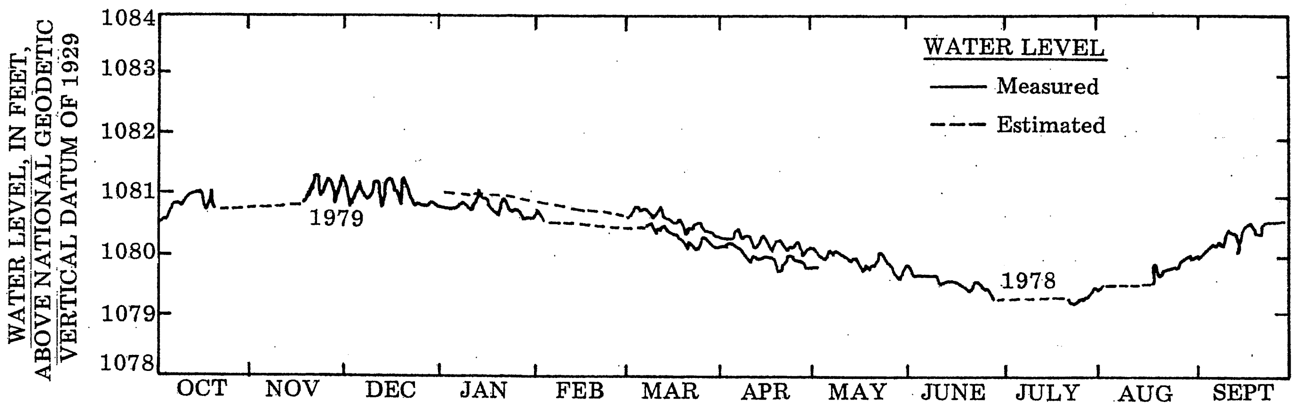
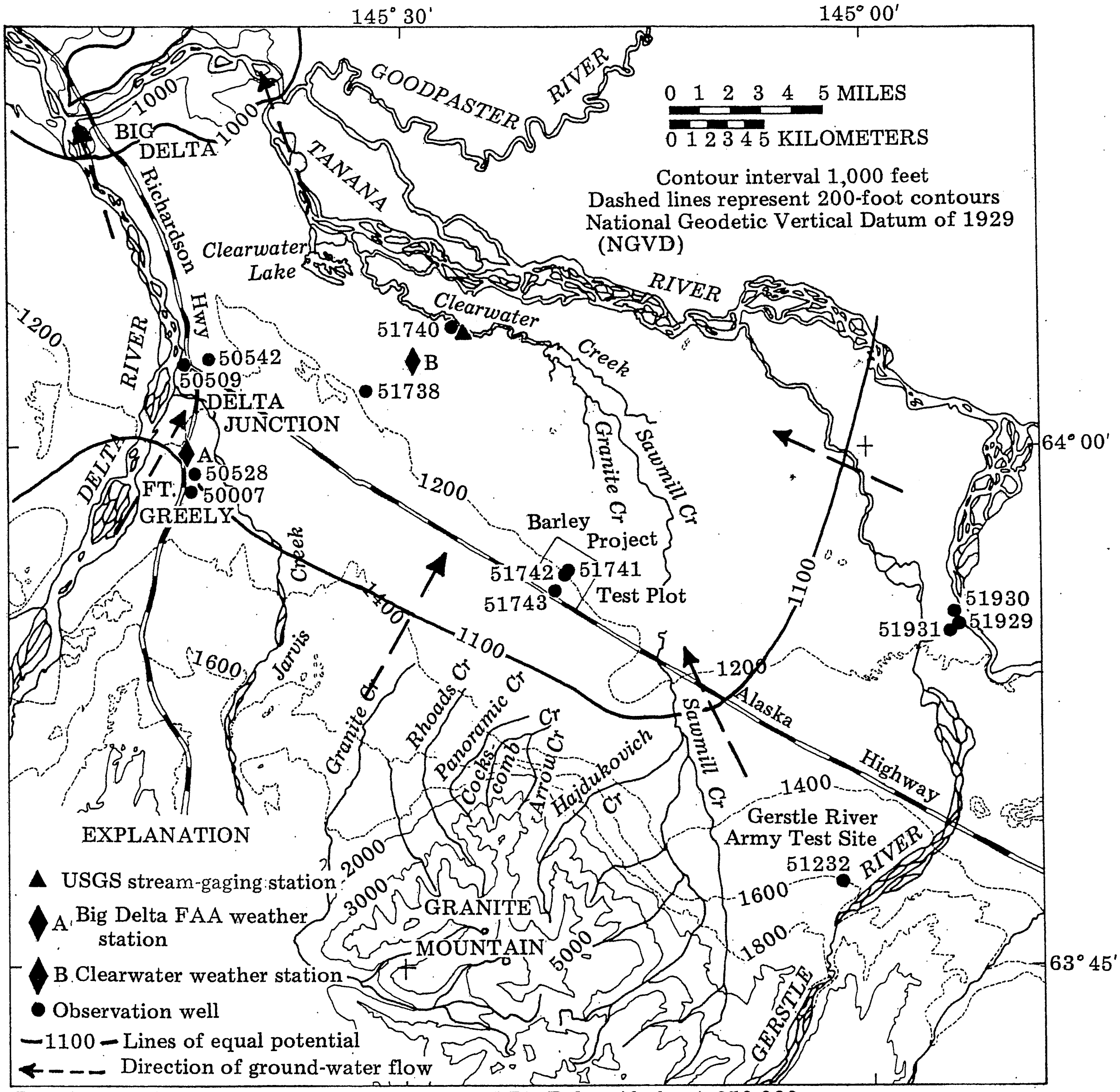


Figure 10.--Hydrograph of well 51743, Barley Project No. 3.

Delta River. The potentiometric surface indicates that ground water recharged by the Delta River and Jarvis Creek flows northeast toward Clearwater Lake. Ground water recharged by the Tanana River along the eastern boundary of the study area, the Gerstle River, and the small creeks draining the north face of the Alaska Range flows toward the Clearwater Creek spring network.

Changes to the land surface during agricultural development may alter the thickness and areal extent of permafrost and affect ground-water/surface-water relationships and, ultimately, flow. Permafrost is an effective barrier to the downward migration of water and water-borne pollutants. However, because downward infiltration is impeded, greater amounts of precipitation may run off as overland flow in areas underlain by permafrost than in permafrost-free areas. This surface runoff, especially in newly cultivated areas, may contribute sediment and topically applied agricultural chemicals to surface-water bodies downslope. As the permafrost level is lowered under tilled fields and elsewhere, surface runoff may decrease as ground-water infiltration increases.



Base from U.S. Geological Survey Mt. Hayes and Big Delta, Alaska, 1:250,000

Figure 11.--Hypothesized hydrologic flow system.

Water Quality

Surface Water

Water-quality analyses are available for 13 surface-water sites in the Delta-Clearwater area. Representative analyses are given in table 2. Complete data are published elsewhere in reports of the Geological Survey; references are given in the following table.

References for U.S. Geological Survey water-quality analyses (WSP - Water-Supply Paper; AK 75-1 and similar abbreviations - Water-Data Report for the given water year.)

Site name	Publication	Page no.
Tanana R at Big Delta 64°09'20" 145°51'00"	WSP 1372 WSP 1466 WSP 1486 WSP 1570 AK-75-1 AK-79-1	184-186, 244 187-190, 238 221 117 331 318
Clearwater Cr nr Delta Jct 64°03'22" 145°26'16"	AK-77-1 AK-78-1 AK-79-1	189 219 223-225
Sawmill Cr 3.0 mi above Granite Cr nr Delta Jct 63°59'48" 145°14'49"	AK-77-1	305
Jarvis Cr nr Delta Jct 64°01'25" 145°43'25"	WSP 1372 WSP 1466 WSP 1486 AK-74-1 AK-75-1 AK-79-1	244 238 222 312 341 318
Granite Cr 0.1 mi above Sawmill Cr nr Delta Jct 64°01'22" 145°18'07"	AK-77-1	306
Tanana R 18 mi above Gerstle R nr Delta Jct 63°55'00" 144°53'55"	AK-79-1	317
Clearwater Lk nr Big Delta 64°05'10" 145°36'00"	AK-79-1	328

Site name	Publication	Page n
Gerstle R nr Big Delta 63°49'00" 144°55'00"	WSP 1372 WSP 1466 WSP 1486 WSP 1500 WSP 1570 AK-79-1	244 235 220 95 116 317
Sawmill Cr nr Big Delta 63°53'55" 145°13'45"	WSP 1372 AK-79-1	244 290, 31
Sawmill Cr 0.2 mi above Granite Cr nr Delta Jct 64°01'23" 145°17'43"	AK-77-1	306
Clearwater Cr 0.1 mi above Sawmill Cr nr Delta Jct 64°02'54" 145°20'14"	AK-77-1	305
Clearwater Lk outlet nr Delta Jct 64°06'23" 145°36'00"	AK-77-1	306
Delta R nr Big Delta 64°07'35" 145°50'00"	WSP 1486 WSP 1500 WSP 1570 AK-75-1 AK-79-1	222 95 117 342 318

Predominant ions in the surface water are calcium and bicarbonate. Percentages of milliequivalents per liter of calcium, magnesium, sodium plus potassium, chloride, sulfate, and carbonate plus bicarbonate for samples collected at selected

Table 2.--Selected water-quality data for surface-water sites in the Delta-Clearwater area. All analyses were for dissolved constituents and are reported in milligrams per liter except where noted.

Date	Streamflow, instantaneous (ft^3/s)	Temperature (°C)	pH (units)	Specific conductance (micromhos)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Nitrite plus nitrate (as N)	Fluoride	Silica	Iron (µg/L)
Clearwater Creek near Delta Junction (at gaging station 0.4 mile downstream from campground) (Station No. 15477500)																	
77/09/05	753	3.5	7.4	300	179	150	46	8.7	3.8	2.1	140	34	1.1	0.16	0.2	14	40
78/02/27	--	2.0	8.0	290	188	150	45	9.4	3.6	2.0	160	31	1.2	.26	.2	15	50
78/08/16	742	5.0	7.5	306	183	150	45	8.6	3.8	2.1	150	33	1.2	.22	.1	14	10
78/10/16	--	1.5	8.2	312	179	140	43	8.2	3.7	2.0	150	31	1.3	.29	.2	14	<10
78/12/06	674	1.0	7.4	315	155	98	31	5.0	2.1	1.3	150	34	1.2	.27	.1	5.3	100
79/03/22	646	1.0	7.6	360	188	160	48	9.0	3.7	2.2	150	36	1.4	.26	.2	12	0
79/05/24	634	5.0	7.2	310	176	150	46	8.5	3.7	2.2	140	33	1.4	.17	.2	11	10
79/06/20	660	8.6	7.8	317	182	140	43	9.1	4.6	2.2	150	31	1.5	.18	.2	15	370
79/07/27	787	7.0	8.0	330	179	140	42	8.8	3.8	2.5	150	32	1.3	.18	.2	14	10
Clearwater Creek 0.1 mile above Sawmill Creek near Delta Junction (64°02'54"N 145°20'14"W)																	
77/08/25	135	3.5	7.7	360	208	180	55	9.5	4.2	2.1	170	37	1.3	.16	.2	14	20
Granite Creek 0.1 mile above Sawmill Creek near Delta Junction (64°01'22"N 145°18'07"W)																	
77/08/25	53	3.0	8.0	310	182	150	45	8.5	3.1	2.2	140	38	.9	.23	.2	14	40
Clearwater Lake near Big Delta (64°05'10"N 145°36'00"W)																	
78/10/16	--	2.0	7.8	289	163	130	38	9.1	2.5	2.5	120	41	1.2	.27	.1	8.5	<10
79/06/20	--	12.0	7.7	271	166	130	38	9.7	2.9	2.6	120	42	1.4	.25	.1	9.2	10
Clearwater Lake outlet near Delta Junction (64°06'23"N 145°36'00"W)																	
77/09/05	463	6.0	8.0	250	155	130	37	9.4	2.8	2.6	110	38	1.2	.13	.1	9.4	30
Sawmill Creek 0.2 mile above Granite Creek near Delta Junction (64°01'23"N 145°17'43"W)																	
77/08/25	209	3.0	7.7	325	--	--	--	--	--	--	150	--	--	--	--	--	--

Table 2.--Selected water-quality data for surface-water sites in the Delta-Clearwater area. All analyses were for dissolved constituents and are reported in milligrams per liter except where noted--Continued.

Date	Streamflow, instantaneous (ft^3/s)	Temperature (°C)	pH (units)	Specific conductance (micromhos)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Nitrite plus nitrate (as N)	Fluoride	Silica	Iron (μg/L)
Sawmill Creek 3.0 miles above Granite Creek near Delta Junction (63°59'48"N 145°14'49"W)																	
77/08/25	49	2.5	7.3	270	196	160	49	8.4	3.7	2.2	160	37	1.4	0.15	0.2	14	20
Sawmill Creek near Big Delta at Alaska Highway Bridge (63°53'55"N 145°13'45"W)																	
49/07/21	--	13.5	6.2	33	--	12	--	--	1.6**		15	1.8	0.2	.13*	--	4.4	--
79/06/20	5.2	13.0	6.4	35	--	--	--	--	--	--	14	--	--	--	--	--	--
Delta River near Big Delta (64°07'?5"N 145°50'00"W)																	
55/05/17	--	--	7.2	205	123	94	27	6.4	2.8	3.8	86	31	1.0	.20*	.0	7.4	--
55/09/20	--	--	7.5	261	153	119	32	9.6	3.9	3.2	102	44	1.8	.09*	.1	8.1	--
56/05/03	--	--	7.7	194	118	91	26	6.3	2.9	3.3	89	27	.2	.11*	.1	8.0	--
56/05/11	--	--	8.0	220	126	101	28	7.5	3.1	3.0	88	35	1.5	.09*	.0	4.7	--
56/09/01	--	9.5	7.9	215	126	98	30	5.6	3.2	2.8	87	33	1.0	.09*	.0	7.4	--
57/09/19	--	--	7.8	252	148	119	28	12	2.7	3.4	98	47	1.0	.02*	.1	5.6	--
58/01/05	--	.0	7.8	266	157	130	38	8.4	2.4	3.6	120	36	1.5	.38*	.0	6.8	--
58/02/14	--	.0	7.3	284	161	130	39	8.0	2.9	4.0	125	36	.5	.31*	.0	7.6	--
78/10/16	--	4.0	8.2	255	156	120	35	7.6	3.0	3.7	110	45	1.0	.28	.1	5.6	<10
79/06/20	--	13.0	7.0	186	103	81	22	6.4	2.4	2.0	76	27	1.2	.11	.1	4.3	40
Tanana River 18 miles above Gerstle River near Delta Junction (63°55'00"N 144°53'55"W)																	
78/10/15	--	--	8.0	290	186	140	43	9.1	5.5	1.4	160	32	2.2	.34	.1	12	10
79/06/20	--	12.0	7.8	218	122	93	27	6.3	5.7	1.4	92	25	3.3	.04	.1	7.8	30

*Value calculated from dissolved nitrate value which was reported as NO_3.
**Sodium and potassium values combined.

Table 2.--Selected water-quality data for surface-water sites in the Delta-Clearwater area. All analyses were for dissolved constituents and are reported in milligrams per liter except where noted--Continued.

Date	Streamflow, instantaneous (ft^3/s)	Temperature (°C)	pH (units)	Specific conductance (micromhos)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Nitrite plus nitrate (as N)	Fluoride	Silica	Iron (µg/L)
Tanana River at Big Delta (Station No. 15478000)																	
49/07/01-10	29,310[1]	--	7.3	209	124	97	28	6.7	4.6	1.8	95	23	2.6	0.18*	0.3	9.1	--
49/08/01-10	50,890[1]	--	7.5	251	148	118	37	6.2	4.0	1.6	118	29	2.1	.13*	.2	9.7	--
49/09/01-10	32,170[1]	--	7.5	251	147	119	36	7.0	4.2	1.4	118	29	1.8	.07*	.2	9.1	--
49/10/01-10	13,720[1]	--	7.6	273	163	130	38	8.6	5.0	2.1	131	31	2.4	.11*	.2	11	--
49/11/01-10	6,680[1]	--	7.6	278	167	134	39	9.0	4.5	2.1	134	30	1.7	.22*	.1	14	--
49/12/01-10	4,670[1]	--	7.5	278	167	132	38	9.0	4.2	2.1	134	32	1.8	.18*	.2	13	--
51/01/01-10	5,910[1]	--	7.4	304	181	146	43	9.5	4.7**		153	31	1.6	.16	.0	15	--
51/02/01-10	4,630[1]	--	7.5	296	174	141	43	8.3	5.8**		148	28	2.2	.04*	.1	14	--
51/03/01-10	4,350[1]	--	7.5	270	155	126	39	7.0	5.0**		122	33	1.1	.29*	--	8.4	--
51/04/01-10	4,882[1]	--	7.9	286	163	133	41	7.5	4.9**		139	26	1.6	.16*	--	13	--
51/05/01-10	12,380[1]	--	6.8	244	145	112	33	7.2	6.4**		116	27	1.4	.22*	--	12	--
51/06/01-10	19,130[1]	--	7.5	249	144	113	33	7.5	5.7**		113	28	2.2	.20*	--	11	--
78/10/16	--	--	7.9	277	160	130	37	8.1	4.1	2.3	130	32	1.4	.21	.1	10	<10
79/06/20	--	13.0	7.4	218	131	97	28	6.5	5.1	1.7	98	29	2.7	.15	.1	8.8	170
Jarvis Creek near Delta Junction at Richardson Highway Bridge (64°01'25"N 145°43'25"W)																	
49/07/07	748	14.0	6.7	170	95	84	22	7.0	0.7**		69	27	.5	.16*	--	3.5	--
49/07/17	--	--	7.0	232	134	118	32	9.4	2.1**		107	32	1.2	.09*	--	4.3	--
51/07/03	--	--	7.5	247	138	119	32	9.5	2.1**		104	33	2.2	.13*	0.1	7.3	--

*Value calculated from dissolved nitrate value which was reported as NO_3.
**Sodium and potassium values combined.
[1] Streamflow, mean (ft^3/s)

Table 2.--Selected water-quality data for surface-water sites in the Delta-Clearwater area. All analyses were for dissolved constituents and are reported in milligrams per liter except where noted--Continued.

Date	Streamflow, instantaneous (ft^3/s)	Temperature (°C)	pH (units)	Specific conductance (micromhos)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Nitrite plus nitrate (as N)	Fluoride	Silica	Iron (µg/L)
Jarvis Creek near Delta Junction at Richardson Highway Bridge (64°01'25"N 145°43'25"W)--Continued																	
53/07/29	--	15.5	7.4	228	131	111	29	9.3	1.3	1.8	87	43	0.2	0.09*	0.1	3.2	--
54/09/27	--	.0	7.4	318	182	155	39	14	2.3	.5	112	66	.4	.11*	.0	3.9	--
55/09/20	--	--	7.7	312	172	151	39	13	2.4	1.2	114	55	.2	.07*	.0	5.2	--
56/08/02	--	--	7.5	227	135	113	29	10	3.1	2.2	96	39	.0	.09*	.3	3.4	--
75/06/25	551	8.0	8.2	204	109	95	26	7.2	2.6	1.1	83	27	1.0	.07	.1	2.7	30
78/10/16	--	--	8.2	362	217	180	46	17	3.5	1.5	150	69	.6	.23	.1	4.9	<10
79/06/20	--	11.0	7.8	182	101	84	21	7.6	1.5	.9	70	30	1.5	.09	.1	3.3	100
Gerstle River near Big Delta at Alaska Highway Bridge (Station No. 15476700)																	
49/07/21	--	11.5	7.1	272	160	138	41	8.5	2.5**		115	45	1.0	.20*	--	4.1	--
51/06/21	--	--	7.7	280	157	125	36	8.5	5.1**		92	54	2.2	.18*	.2	5.3	--
52/08/26	--	5.5	7.5	248	151	125	34	9.8	1.9	1.7	85	57	1.0	.11*	.2	3.6	--
53/05/13	--	2.0	7.2	244	147	119	36	7.0	2.4	1.7	82	55	1.0	.11*	.2	3.1	--
53/07/29	--	10.5	7.4	214	119	97	28	6.5	1.3	3.0	78	37	.0	.04*	.9	3.8	--
54/09/18	--	--	7.4	304	179	148	41	11	2.9	2.2	93	70	.5	.11*	.3	4.7	--
55/05/17	--	--	6.8	199	113	92	27	5.9	1.4	1.7	66	38	.8	.11*	.4	4.7	--
55/09/20	--	--	7.6	340	205	167	47	12	3.7	2.7	117	74	1.2	.11*	.4	5.6	--
56/05/11	--	--	7.5	171	103	83	25	5.0	1.3	2.0	59	38	.5	.00	--	2.4	--
56/06/15	--	--	7.8	196	114	90	26	6.1	3.1	1.8	71	34	2.8	.22*	.4	3.7	--

*Value calculated from dissolved nitrate value which was reported as NO_3.
**Sodium and potassium values combined.

Table 2.--Selected water-quality data for surface-water sites in the Delta-Clearwater area. All analyses were for dissolved constituents and are reported in milligrams per liter except where noted--Continued.

Date	Streamflow, instantaneous (ft^3/s)	Temperature (°C)	pH (units)	Specific conductance (micromhos)	Dissolved solids, sum of constituents	Hardness as $CaCO_3$	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Nitrite plus nitrate (as N)	Fluoride	Silica	Iron (µg/L)
Gerstle River near Big Delta at Alaska Highway Bridge (Station No. 15476700)--Continued																	
56/08/03	--	13.0	7.6	235	141	109	30	8.4	2.1	2.0	86	49	0.8	0.07*	0.3	6.2	--
56/09/01	--	8.0	6.8	247	148	122	35	8.5	2.3	2.1	81	54	.8	.09*	.2	5.1	--
57/09/18	--	--	7.7	291	173	141	35	13	2.1	2.0	92	71	1.5	.07*	.1	3.0	--
58/05/06	--	.0	7.7	243	167	140	38	11	2.4	2.0	98	60	.5	.13*	.6	3.6	--
58/06/04	--	11.0	7.3	213	122	101	30	6.3	1.8	2.2	80	36	1.5	.07*	.6	3.9	--
58/06/24	--	8.5	7.5	226	132	108	30	8.2	2.0	2.2	79	45	1.5	.02*	.6	3.1	--
58/08/27	--	9.0	7.7	265	154	128	33	11	2.1	1.8	82	62	1.0	.02*	.4	2.7	--
78/10/15	--	--	8.0	335	214	180	52	11	3.7	2.3	120	78	1.8	.54	.6	3.5	<10
79/06/20	--	10.0	7.8	205	114	93	26	6.8	1.7	1.5	72	39	.9	.04	.3	2.2	30

*Value calculated from dissolved nitrate value which was reported as NO_3.

sites during this study are shown on a trilinear diagram (fig. 12). Samples from the Gerstle River, Delta River, Jarvis Creek, and Clearwater Lake had higher percentages of sulfate than the Clearwater Creek and Tanana River samples. Plotted values for Clearwater Lake, Jarvis Creek, and the Delta River are in close proximity, indicating similar water quality. The plots for Clearwater Creek, the Tanana River at Big Delta, and the Tanana River 18 mi above the Gerstle River also lie proximate.

The similarities of surface-water quality in the discharge and recharge areas of the alluvial aquifer seem compatible with the hypothesized hydrologic flow system. For example, the similarity of water quality in Clearwater Lake, the Delta River, and Jarvis Creek supports the hypothesis that the section of the aquifer discharging at Clearwater Lake is recharged by channel losses from the Delta River and Jarvis Creek. However, this apparent compatibility may also be a result of the influence on water quality by the sediment with which the water comes in contact. Thus, the chemical quality of water in Clearwater Lake, Jarvis Creek, and the Delta River may be similar because the materials near the lake were derived from the Delta River-Jarvis Creek drainage areas.

Ground Water

Ground-water quality was not intensively analyzed during this study, largely because of a lack of wells near the agricultural development area. Some water-quality data are available for wells along the Richardson Highway, at Fort Greely, and for the well at the Gerstle River Army Test Site. Predominant ions in the ground water are calcium and bicarbonate, and all samples plot within a small area on a trilinear diagram (fig. 13). Concentrations of constituents were similar in all wells tested with the exception of the well at the Gerstle River Army Test Site in which the concentrations were higher (table 3). However, the variation in percentages of milliequivalents per liter among all the ground-water samples is even less than the variation in the surface-water samples. Analyses of water from the well at the Gerstle River Army Test Site and from three other wells in the vicinity of Delta Junction and Fort Greely are shown in table 3. Temperatures of the ground water in the area are generally between 2° and 5°C. The higher temperatures shown for two of the samples (7.2° and 9.0°C) indicate that those samples may not be representative of the fresh ground water and, therefore, that other chemical constituents in the analyses may not accurately portray the ground-water quality. However, the analyses shown are representative of the historical data that exist for the wells in the Delta-Clearwater area.

CONCLUSIONS

Hydrologic observations and data analysis indicate that the sections of the aquifer that discharge at Clearwater Lake and near Big Delta are recharged largely by seepage losses from the Delta River and Jarvis Creek. Similarly, it appears that the sections of the aquifer that discharge at the Clearwater Creek network receive recharge from the Tanana River along the eastern boundary of the study area, the Gerstle River, and several small creeks draining the north face of the Alaska Range. Additional data are needed to improve confidence that this conceptual hydrologic flow model is correct. Specifically, ground-water level data are needed, especially in the eastern and central parts of the study area. Additional measurements of aquifer recharge and discharge are also needed.

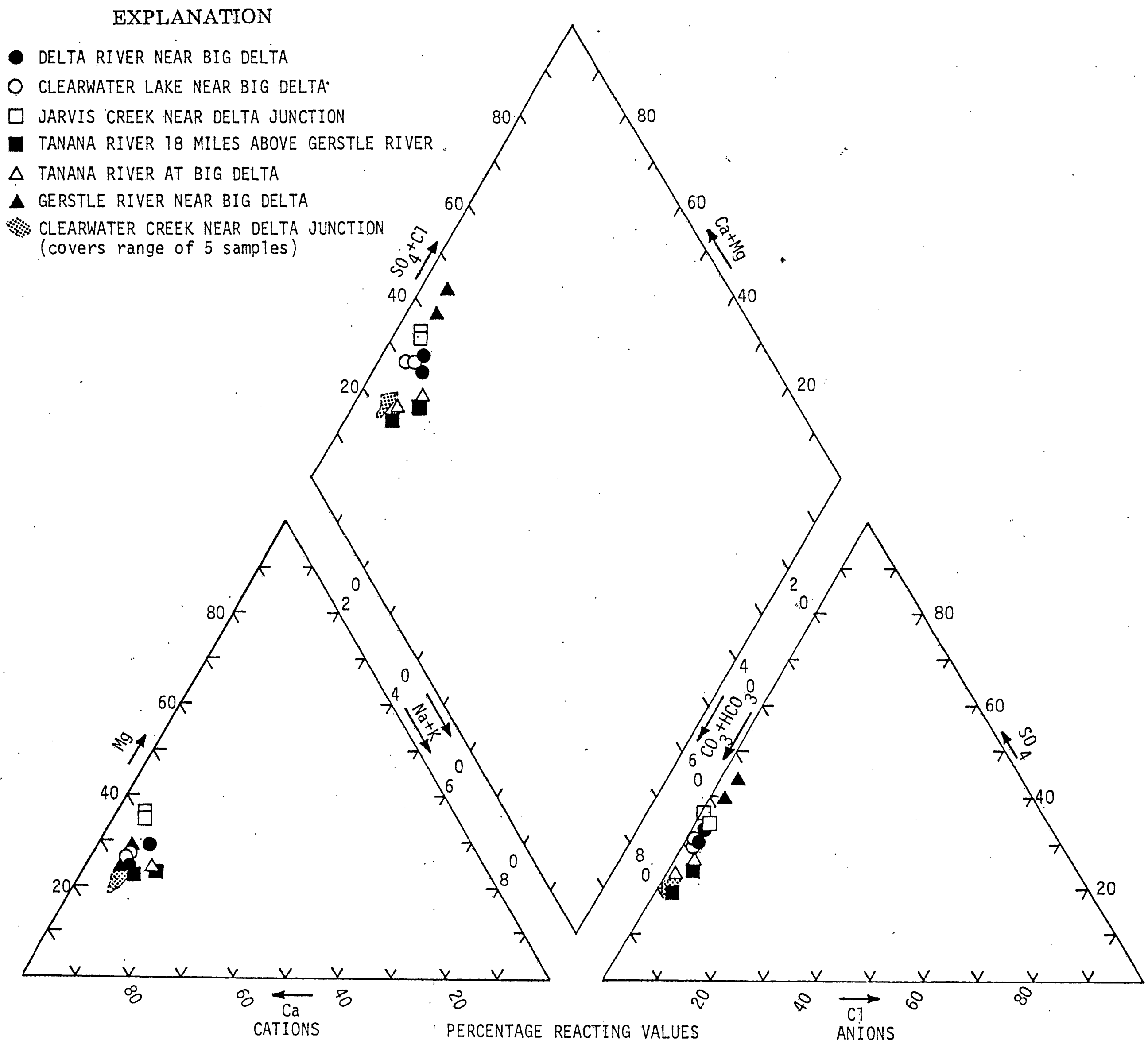


Figure 12.--Trilinear diagram of surface-water quality analyses in the Delta-Clearwater area.

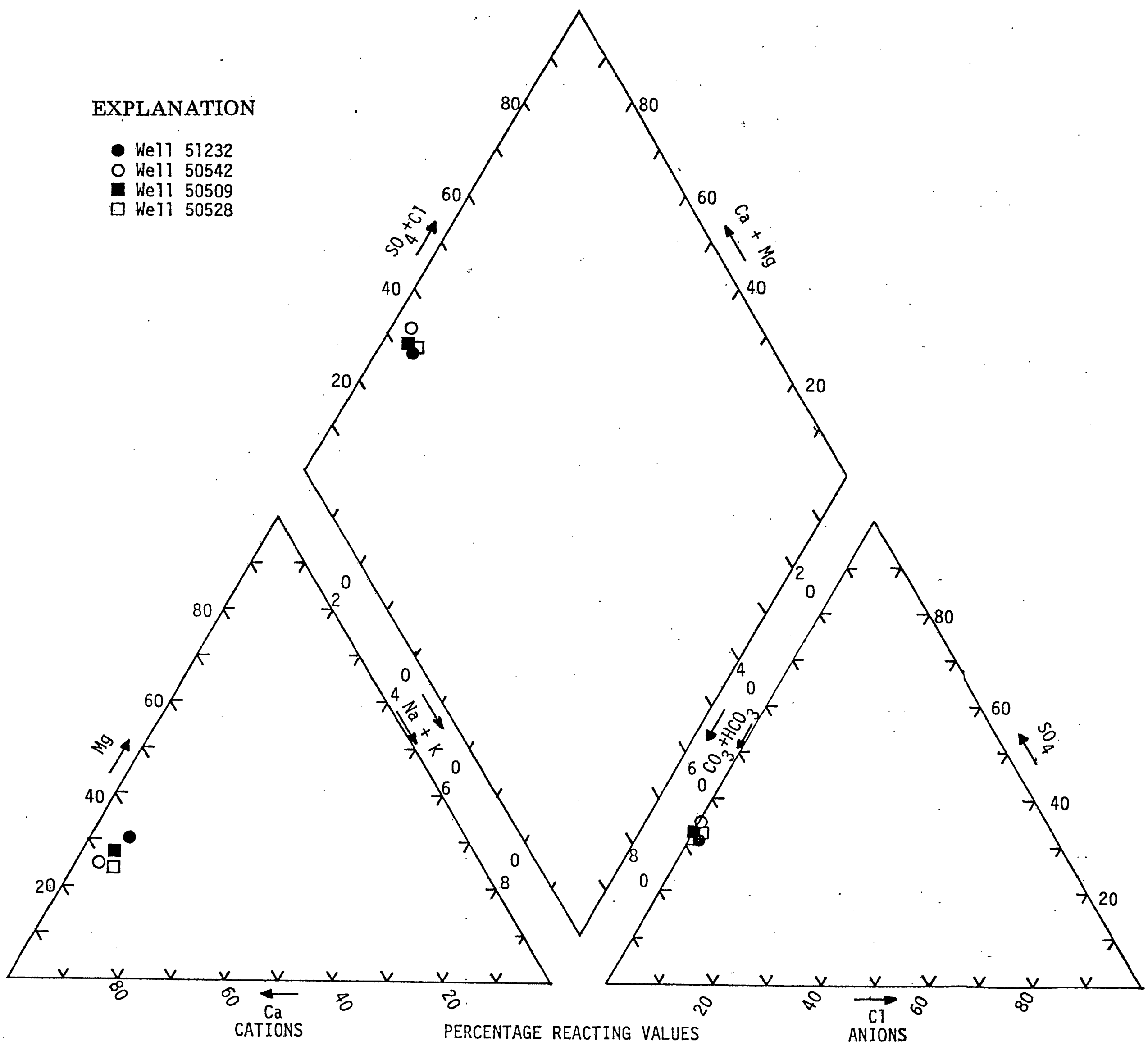


Figure 13.--Trilinear diagram of ground-water quality analyses in the Delta-Clearwater area.

Table 3.--Water-quality data from ground-water sites in the Delta-Clearwater area. All analyses were for dissolved constituents and are reported in milligrams per liter, except where noted.

	Well 51232 Gerstle River Army Test Site	Well 50542 Delta Junction School	Well 50509 Bay Hotel	Well 50528 Fort Greely No. 1
	April 3, 1969	June 18, 1968	June 18, 1968	September 16, 1970
Specific conductance (micromhos per centimeter at 25°C)	559	231	236	260
pH (units)	8.3	7.8	7.9	8.2
Water temperature (°C)	7.2	Missing	9.0	4.0
Hardness (total)	290	110	110	130
Hardness (noncarbonate)	88	25	31	38
Calcium	78	32	32	38
Magnesium	23	7.1	8.0	8.2
Sodium	8.3	1.8	2.7	2.6
Potassium	3.0	2.7	2.5	3.6
Bicarbonate	246	102	100	110
Sulfate	92	36	38	42
Chloride	3.5	0.4	0.8	1.5
Fluoride	0.8	0.0	0.2	0.2
Silica	6.7	7.9	8.2	6.1
Residue (calculated)	340	138	142	156
Nitrate as N	3.9	0.1	0.6	0.1
Iron	0.0	0.18	0.20	0.02

Without the benefits of several aquifer tests that are needed within the study area, the potential drawdown that will be caused by ground-water withdrawal for irrigation is largely unknown. Thus the potential effect of irrigation on the Clearwater Creek network cannot be assessed.

Water quality in the aquifer and in Clearwater Creek may be affected by agricultural development. Ground water passing beneath the agricultural area flows toward the Clearwater Creek network. Agricultural chemicals that infiltrate to the aquifer may be transported through the aquifer to springs feeding the creeks. Additionally, overland flow from cultivated areas may cause changes in the physical and chemical quality of the spring-fed creeks. Sediment, dissolved solids, nutrients, biota, and temperature may be affected.

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Table A.--U.S. Geological Survey downstream order numbers for sites in the Delta-Clearwater area

Station name	Station number	Latitude and Longitude	
Gerstle River near Big Delta	15476700	63°49'00"	144°55'00"
Clearwater Creek near Delta Junction	15477500	64°03'22"	145°26'16"
Tanana River at Big Delta	15478000	64°09'20"	145°51'00"